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QUALITATIVE AND QUANTITATIVE COMPOSITION OF THE ICHTHYOFAUNA OF THE SAVICA LAKES

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ABSTRACT

The Savica significant landscape is the only wetland area within the boundaries of the city of Zagreb and as such is of great value. The lake comprises a small section of an old arm of the Sava River, and 13 interconnected lakes created by the expansion of old lake arms. In terms of its biological classification, it is a eutrophic lake and provides adequate conditions for the survival of fish populations. The aim of the study was to investigate the qualitative and quantitative composition of the ichthyofauna in Lake Savica, while determining biodiversity indices, the presence of nonnative species and species composition by trophic and ecological groups. Sampling was carried out by electrofishing at 11 sites in the important landscape of Savica. A total of 20 fish species were recorded, of which 7 were non-native species. These results were compared with previous surveys of the lake. Lake Savica is inhabited by fish from standing waters of the lowlands, and the species present are generally opportune, with some interesting species for sport fishing.

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INTRODUCTION

Savica Lake is an extremely important area for the city of Zagreb with about 770,000 inhabitants (GUGEOSP, 2022) because its proximity to the city center is a suitable place for enjoying nature and a place for holding ecological education for citizens, especially students and pupils (ŠRD Pešćenica, 2023). The Savica significant landscape includes a part of the old arm of the Sava River (called Stara Savica) and 13 lakes, interconnected by bridges (PI Maksimir, 2023). The significance of this landscape was recognised by the Assembly of the City of Zagreb in 1991, when it passed the decision to proclaim the area a significant landscape with separate special zoology reserve (SGGZ, 13/91). Savica is mostly used for recreational fishing as a part of river Sava fishing area (NN 14/2022). It falls within the Sava fishing area, Zagreb East fishing zone (NN 14/2022), and the fishing rights are managed by the Pešćenica sports fishing club pursuant to the Freshwater Fisheries Act, and sports fishing is managed according to the Fishing Zone Management Plan (PI Maksimir, 2022).
In terms of the landscape, the Savica area is classified as a lowland river area with mixed landscape. The landscape extends along both banks of the Sava River, from Podsused in the west to Jakusevac and Zitnjak in the east.

The Sava River landscape has been recognised as an area of the highest landscape vulnerability, alongside the general landscapes of Mt. Medvednica and the lowland urban landscape of the City of Zagreb (Koščak Miočić-Stošić et al., 2015). Savica is the only wetland area in the Zagreb agglomeration and its main characteristics are the aquatic and wet habitats, and their associated biodiversity. With river regulation, the diversity of aquatic and wet habitats and associated species has been heavily impacted (PI Maksimir, 2022). The old backwaters and river arms have mostly been lost or dried out due to a lowering of the water table. The former gravel and sandy banks of the Sava River within the Zagreb city limits are now rare, remaining mostly only along the gravel extraction pits and artificial lakes formed from them (Tvrtković et al., 2007). In terms of ichthyology, the Savica lakes are a lowland water type and are inhabited by warm-water fish families, particularly the carps (Cyprinidae), loaches (Cobitidae), catfishes (Siluridae), pike (Esocidae), and perches (Percidae). Non Native Species (NNS) or Non Indigenous warm-water fish species are also found here, such as those from the families Ictaluridae, Centrarchida and Poecillidae (Mrakovčić et al., 2007).

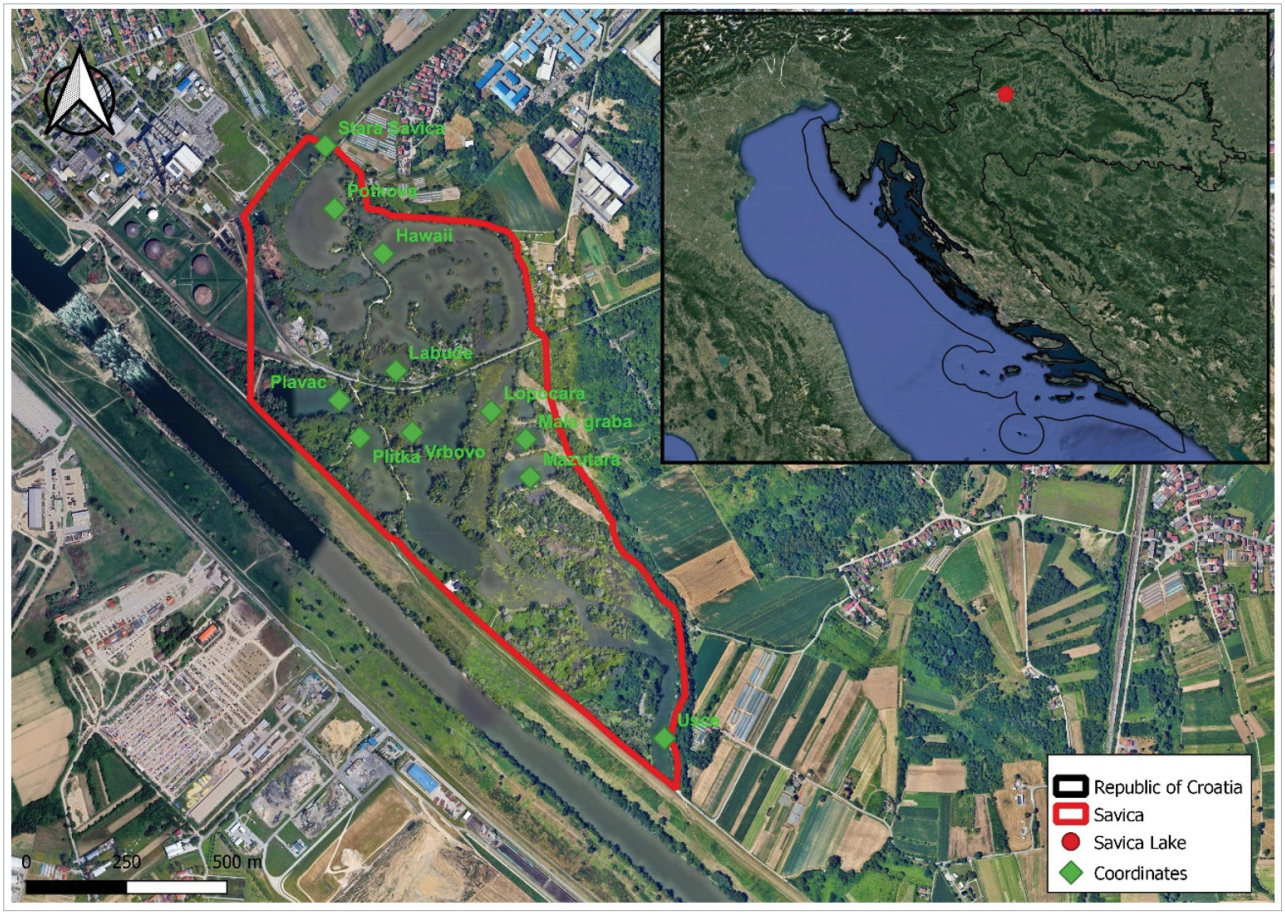

Fig 1. Sampling area and sampling stations, created in program QGIS

MATERIAL AND METHODS

Sampling was performed at 11 selected locations on three sampling days (Figure 1). Sampling was aimed at collecting data on the fish community in the old river arm and 10 of the Savica Lakes over a 6-month period (May to October 2023), once in each season (spring, summer, autumn). Electrofishing was performed from a boat as a standard ichthyological method using a Hans Grasslo, 7.5 kW electrofisher connected to a rounded stainless steel anode of 50 cm diameter with a mesh size of 10 mm (based on the license for year 2023. issued by Min. of Agriculture, Fisheries Administration from 9th of February 2023, CLASS UP/I-324-01/23-01/33, Ed. No. 525-12/733-23-4). This method is primarily selected for adult fish. The minimum sampling transect varied by sample site due to lake size, though sampling from the boat along the shore was limited to 25 minutes, and a GPS device was used to measure the distance covered. All observed individuals were determined to the species level on the basis of external morphological traits, and individuals were counted. The Savica Significant Landscape falls within a nature protection category, and for that reason, biomass was not recorded.

To determine the qualitative and quantitative analysis of the fish community composition, and to analyse the abundance of alien freshwater species in the Savica Lakes, the basic functions of Microsoft Excel were used. The program PRIMER 6.0 was used for the statistical analysis to determine similarities between fish communities at different sampling sites (Bray-Curtis similarities, Cluster analysis), with significance set at a value of $P < 0.05$. The Simpson Index, Shannon-Weiner Index, Brillouin Index and Margalefov Index were used in PRIMER 6.0 to analyse biodiversity.

Table 1. Systematic overview of the fish species and families recorded in the Savica Lakes

Family	Species - Latin name	English name	Native/alien species
Cobitidae	*Cobitis elongatoides* Băcescu & Mayer, 1969	Danubian spined loach	Native
Cyprinidae	*Cyprinus carpio* Linnaeus, 1758	Common carp	Native
	Carassius gibelio (Bloch, 1782)	Prussian carp	Alien
Xenocyprididae	*Ctenopharyngodon idella* (Valenciennes, 1844)	Grass carp	Alien
Acheilognathidae	*Rhodeus amarus* (Bloch, 1782)	Bitterling	Native
Gobionidae	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	Topmouth gudgeon	Alien
Leuciscidae	*Scardinius erythrophthalmus* (Linnaeus, 1758)	Rudd	Native
	Alburnus alburnus (Linnaeus, 1758)	Bleak	Native
	Rutilus rutilus (Linnaeus, 1758)	Roach	Native
	Vimba vimba (Linnaeus, 1758)	Vimba	Native
	Squalius cephalus (Linnaeus, 1758)	Chub	Native
Siluridae	*Silurus glanis* Linnaeus, 1758	Catfish	Native
Ictaluridae	*Ameiurus melas* (Rafinesque, 1820)	Black bullhead	Alien
Esocidae	*Esox lucius* Linnaeus, 1758	Pike	Native
Poeciliidae	*Gambusia holbrooki* Girard, 1859	Eastern mosquitofish	NNS
Percidae	*Perca fluviatilis* Linnaeus, 1758	Perch	Native
	Gymnocephalus cernua (Linnaeus, 1758)	Ruffe	Native
	Sander lucioperca (Linnaeus, 1758)	Pike-perch	Native
Centrarchidae	*Lepomis gibbosus* (Linnaeus, 1758)	Pumpkinseed	NNS
	Micropterus salmoides (Lacepède 1802)	Largemouth bass	NNS

RESULTS AND DISCUSSION

Qualitative composition of the fish community

In the Savica Significant Landscape, a total of 6021 fish belonging to 20 species and 12 families were caught, with seven species identified as NNS (Table 1). The fish community of the study area is more species poor than the community of the Sava River (Ćaleta et al., 2019). According to Ćaleta et al. (2019), the Sava River is inhabited by 68 species of freshwater fish, while only one-third of these were confirmed present in the Savica Lakes area. The total number of fish caught was less than expected for this type of habitat (Mrakovčić et al., 2007). The most abundant family was Leuciscidae with five species. Percidae was represented with three species: *Perca fluviatilis* Linnaeus, 1758 (perch), *Gymnocephalus cernua* (Linnaeus, 1758) (ruffe) and *Sander lucioperca* (Linnaeus, 1758) (pike-perch). The family Centrarchidae was represented with two alien species: *Lepomis gibbosus* (Linnaeus, 1758) (pumpkinseed) and *Micropterus salmoides* (Lacepède 1802) (largemouth bass). The family Cyprinidae was represented with one indigenous species *Cyprinus carpio* Linnaeus, 1758 (common carp) and one alien species *Carassius gibelio* (Bloch, 1782) (Prussian carp) (Table 1).

In terms of ecological preference and habitat type, euritopes were dominant, while in terms of reproduction and spawning substrate, the phytophiles were dominant (Mustafić et al., 2020), which is not surprising since the majority of lakes are characterised by having abundant aquatic vegetation. There was also one ostracophil (*Rhodeus amarus* (Bloch, 1782) - bitterling), a species that lays its eggs in the gill openings of bivalves. In terms of nutritional strategy, most of the fish recorded are omnivorous, with a few exceptions of piscivorous and herbivorous species (Table 2).

Table 2. Ecological traits of freshwater fish species recorded in the Savica Lakes (according to Aarts & Nienhuis, 2003; Mihaljević et al., 2011; Mustafić et al., 2020; Rauch, 2022)

Species	Ecological habitat preference	Water column	Spawning substrate	Feeding strategy
Danubian spined loach	Rheophilic	Benthic	LITO	INS/INV
Common carp	Eurytopic	Benthic	FITO	OMNI
Prussian carp	Eurytopic	Benthic	FITO	OMNI
Grass carp	Eurytopic	Benthic	LITO	HERB
Bitterling	Eurytopic	Water column	OSTR	OMNI
Topmouth gudgeon	Eurytopic	Water column	FITO/LITO	OMNI
Rudd	Limnophilic	Benthic	FITO	OMNI
Bleak	Eurytopic	Water column	FITO/LITO	OMNI
Roach	Eurytopic	Water column	FITO/LITO	OMNI
Vimba	Rheophilic	Benthic	LITO	INS/INV
Chub	Rheophilic	Water column	LITO	OMNI
Catfish	Eurytopic	Benthic	FITO	OMNI
Black bullhead	Limnophilic	Benthic	FITO/LITO	OMNI
Pike	Eurytopic	Water column	FITO	PISC
Eastern mosquitofish	Limnophilic	Water column	VIVIP	OMNI
Perch	Eurytopic	Water column	FITO/LITO	INV/PISC
Ruffe	Eurytopic	Benthic	FITO/LITO	INS/INV
Pike-perch	Eurytopic	Water column	FITO	PISC
Pumpkinseed	Limnophilic	Water column	FITO/LITO	INS/INV
Largemouth bass	Eurytopic	Benthic	LITO	OMNI

Abbreviations: LITO - lithophile, FITO - phytophile, OSTR - ostracophil, VIVIP - viviparous, INS - insectivore, INV – invertivore, OMNI - omnivore, HERB - herbivore, PISC – piscivore

The alien species recorded were found in every lake in the study area. A high ratio of alien fish indicates degradation of the habitat and reduced biodiversity. Most alien fish were introduced into Croatian waters for the purpose of aquaculture or sports fishing, while a few were intended as aquarium species (Prussian carp and pumpkinseed) (Mrakovčić et al., 2006). *Gambusia holbrooki* Girard, 1859 (Eastern mosquito fish) was the only species introduced for the purpose of biological control of mosquitos with the aim of combatting malaria (Mihinjač et al., 2019) and its survival in the Savica Lakes can be attributed to the release of warm water effluent from the Zagreb wastewater treatment facility. The Pešćenica sports fishing society is permitted unlimited catches (and prohibition of returning to the water) for all alien species (except *Ctenopharyngodon idella* (Valenciennes, 1844), grass carp) so as to reduce the abundance of those species and improve the state of the fish fauna in the lakes (ŠRD Pešćenica, 2023). The presence of common carp and grass carp is expected, as stocking with these species is performed three times each year (Zanella et al., 2021).

Quantitative composition of the fish fauna

The most abundant fish caught in the sample was the *Alburnus alburnus* (Linnaeus, 1758) (bleak) (26.16%), pumpkinseed (22.01%) and *Rutilus rutilus* (Linnaeus, 1758) (roach) (21.01%). Other species accounted for less than 5% of the total sample, with the exception of Eastern mosquito fish with 10.38% (Figure 2).

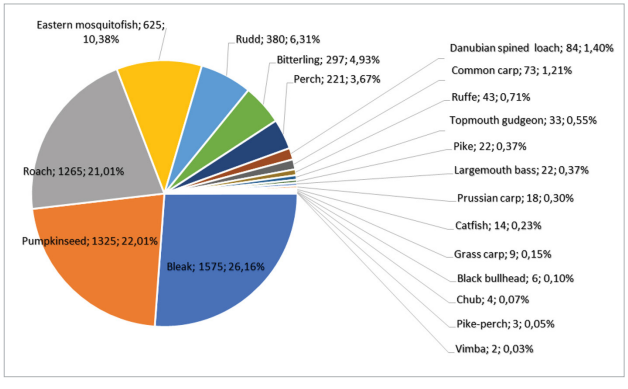

Fig 2. A Pie Chart displaying number and ratio (%) of freshwater fish caught in the Savica Lakes

Bleak can be found in the open waters of the lake, and in lakes of all sizes (Kottelat & Freyhof, 2007), and it has a rapid generation time (Mrakovčić et al., 2007). Bleak is of little interest for commercial or sports fishing due to its small size (Welcomme, 1988), and it is more commonly used as a bait fish since it is one of the most important prey species for the lake predators. Unlike perch, bleak can tolerate high levels of pollution. The large population indicates a lower degree of succession, or a state of stress in the ecosystem (Mrakovčić et al., 2007). The high adaptability of this species explains its strong abundance in the study area. Pumpkinseed is a significant threat for the native fish community since it is highly aggressive and feeds on the eggs and fry of other freshwater fish species. Its aggressive behaviour is overtaking the native fish species that can be found in the Savica Lakes area (Mihinjač et al., 2019). The roach is a fish that keeps in shoals and feeds near the lake bottom. It's most abundant in nutrient-rich lakes and it takes advantage of channelization and slight organic pollution. It can grow to lengths of 1 kilogram and live up to 13 years (Kottelat & Freyhof, 2007).

Qualitative composition of the fish fauna

The highest species richness was found in Lopočara Lake was a total of 14 species including 5 alien species, which the Mala Graba Lake had the lowest species richness with 8 species. Lopočara Lake is characterised by a high cover of aquatic plants, and the presence of a large number of phytophilic species. Alien species were recorded in all studied sampling sites, with the highest number (5 species) recorded at Lopočara Lake, though the largest ratio of alien fish species was in Mazutara Lake (40%). the lowest ratio of alien species was in the Ušće Lake, with two alien species (18.18%). The highest Margalef Index (species richness) was obtained for Lopočara Lake (1.998), and the lowest for Mala Graba Lake (1.202) (Table 3). Of all the lakes, Vrbova Lake had the highest biodiversity index value, while Mala Graba Lake had the lowest. Mala Graba Lake is separated from the remaining lakes by a long, narrow channel, with dense aquatic vegetation. In an earlier survey (Mrakovčić et al., 2007), 21 fish species were recorded with total number of 2780 of caught individuals. Species richness in this survey is somewhat lower than Mrakovčić et al. (2007) study but comparing the number of caught individuals, the number of species is almost the same. This is interesting because in this survey, the fish catch is almost three times higher than the Mrakovčić et al. (2007) survey done 15 years ago. It can be concluded that Savica Lakes are inhabited by around 20 species.

The Bray-Curtis similarity index showed the highest similarity between Plavac and Plitka Lakes, where 11 of the same species were recorded (similarity of 91.14), and the lowest between Mala Graba and Potkova Lakes (28.28) Table 4. According to the CLUSTER analysis (Figure 3), based on the Bray-Curtis similarity ($P < 0.05$), Labuđe and Ušće Lakes statistically differed the most of all the lakes. Plavac and Plitka Lakes formed a cluster with a minimum 90% similarity in the lake ichthyofauna, Hawai and Potkova Lakes formed a second cluster with minimum 80% similarity, while Mazutara Lake joined the first cluster to form a third cluster with a minimum 70% similarity. Plavac and Plitka Lakes are well connected, with similar hydrological properties. Hawai and Potkova Lakes have a strong similarity in fish species due to their physical connection.

Table 3. Number of species, individuals, ratio of alien species, species richness and biodiversity indices for the sampling sites on the Savica Lakes

Lake	S	N	Native species	Alien species	% Alien species	d	HB	H'	1-D
Ušće	11	567	9	2	18.18	1.577	1.674	1.712	0.777
Plavac	11	620	8	3	27.27	1.555	1.586	1.622	0.753
Hawai	11	719	7	4	36.36	1.520	1.476	1.506	0.693
Potkova	13	488	9	4	30.77	1.939	1.555	1.604	0.693
Lopočara	14	669	9	5	35.71	1.998	1.531	1.568	0.722
Mazutara	10	373	6	4	40.00	1.520	1.594	1.642	0.773
Mala graba	8	339	5	3	37.50	1.202	1.271	1.313	0.657
Stara Savica	10	623	7	3	30.00	1.399	1.594	1.625	0.774
Plitka	13	657	9	4	30.77	1.850	1.641	1.678	0.769
Labuđe	12	657	8	4	33.33	1.696	1.662	1.697	0.780
Vrbova	10	309	7	3	30.00	1.570	1.768	1.831	0.798

Abbreviations: S – total number of species, N – total number of individuals, d - Margalef index, HB - Brillouin index, H' - Shannon-Wiener index, 1-D - Simpson index

Table 4. Bray-Curtis similarity matrix between sampling sites in the Savica Lakes

	Ušće	Plavac	Hawai	Potkova	Lopočara	Mazutara	Mala graba	Stara Savica	Plitka	Labuđe	Vrbova
Ušće											
Plavac	47.33										
Hawai	44.55	62.28									
Potkova	43.39	51.07	84.19								
Lopočara	38.92	61.73	61.04	57.79							
Mazutara	35.86	75.90	56.39	44.63	50.90						
Mala graba	31.42	73.47	39.83	28.28	54.95	61.39					
Stara Savica	39.46	57.91	66.54	61.16	51.38	71.51	35.47				
Plitka	49.95	91.14	69.83	58.47	67.92	75.19	66.77	64.86			
Labuđe	54.11	62.91	49.53	47.65	30.14	66.18	44.60	56.41	57.99		
Vrbova	48.92	57.05	72.25	62.66	62.94	52.31	47.30	55.14	64.25	45.96	

Electrofishing is an effective method for assessing the ichthyofauna, though some species may be more difficult to capture. According to previous research of the Savica Lakes (Mrakovčić et al., 2007), in addition to the species found in this present study, other species were also recorded: common bream (*Ambramis abrama* (Linnaeus, 1758)), asp (*Leuciscus aspius*), barbel (*Barbus barbus* (Linnaeus, 1758)), white bream (*Blicca bjoerkna* (Linnaeus, 1758)), tench (*Tinca tinca* (Linnaeus, 1758)) and silver carp (*Hypophthalmichthys molitrix* (Valenciennes, 1844)). However, the present study found four species not recorded in the Mrakovčić et al. (2007) study: *Vimba vimba* (Linnaeus, 1758) (vimba), bitterling, *Pseudorasbora parva* (Temminck & Schlegel, 1846) (topmouth gudgeon) and grass carp. In the light of these varying results over a 15-year period, further monitoring of these lakes is required to better understand the fish community in this important urban habitat.

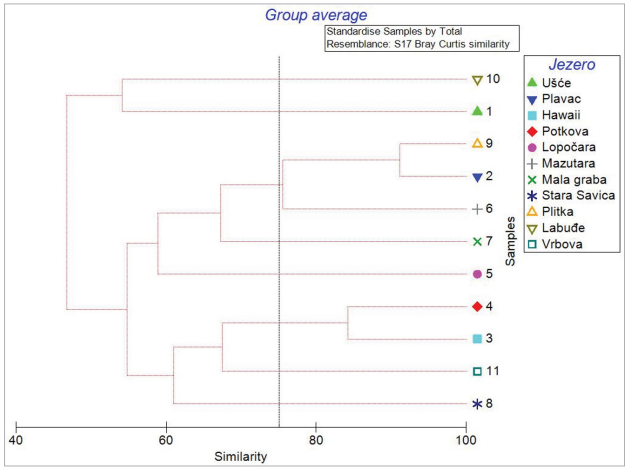

Fig 3. CLUSTER analysis based on the Bray-Curtis similarities of the studied Savica Lakes (vertical line is the limit of Bray-Curtis similarity of 75; *P* value < 0.05)

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KVALITATIVNI I KVANTITATIVNI SASTAV IHTIOFAUNE JEZERA SAVICA

SAŽETAK

Značajni krajobraz Savica je najvrijednije i jedino močvarno područje grada Zagreba. Savica obuhvaća manji dio starog rukavca rijeke Save te 13 međusobno povezanih jezera nastala proširivanjem starih riječnih rukavaca. Jezera, prema biološkoj klasifikaciji, pripadaju eutrofnim jezerima te pružaju sve uvjete za život i napredak populacija riba. Cilj istraživanja bio je istražiti kvalitativni i kvantitativni sastav ihtiofaune jezera Savica te istovremeno odrediti indekse bioraznolikosti, zastupljenost alohtonih vrsta i odrediti zastupljenost vrsta prema trofičkim i ekološkim grupama. Uzorkovanje se provodilo na 11 prethodno određenih lokacija, na području značajnog krajobraza Savica. Uzorkovanje je provedeno elektroribolovom. Za analiziranje ihtiofaune korištene su osnovne funkcije u Microsoft Excel-u i indeksi bioraznolikosti. Zabilježeno je ukupno 20 vrsta riba, od kojih je 7 alohtono. Dobiveni rezultati uspoređeni su s prijašnjim istraživanjem jezera. Rezultati su pokazali da jezera Savica nastanjuju ribe nizinskog tipa stajaćih voda, vrste su generalno oportunističke s pokojom športsko zanimljivom vrstom.

Ključne riječi: značajni krajobraz Savica, bioraznolikost, riblje zajednice, alohtone vrste

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